ANNEX L

GUIDELINES FOR SUBMITTING GPS RELATIVE POSITIONING DATA

Global Positioning System (GPS) relative positioning data submitted to the National Geodetic Survey (NGS) of the National Oceanic and Atmospheric Administration for inclusion in the National Geodetic Reference System (NGRS) must meet the following requirements.

1.0 GPS RAW OBSERVATIONS (R-files): The raw GPS observations will be sent to NGS in a format specified by NGS at the time of submission. Each R-file consists of the set (one or more data files) of raw GPS data for each unique (independent) occupation of a station. For example, if there were four receivers observing during each of five sessions a total of 20 raw data sets would be collected.

2.0 GPS VECTOR SOLUTIONS (G-file): The unadjusted vectors will be submitted in the format specified in ANNEX N. Submit one G-file for each GPS survey project. The G-file may be generated from one of the following: (1) a subroutine of the GPS vector processing software; (2) a stand-alone program that reads the printer output file of the vector processing software; or (3) software that prompts the user for keyboard entries such as CR8G (NGS 1988).

The G-file contains such information as:

(1) From/to station identification
(2) Vector coordinate differences (DX, DY, DZ), standard deviations, correlations (or covariance data)
(3) Name of processing software and version
(4) Date of solution
(5) Source of the ephemerides
(6) Coordinate system (datum) for the vectors
(7) Method of reduction (i.e., fixed or adjusted orbit solutions, single session or network reduction mode, and single or dual frequencies).

When processing data from two stations at a time, the technique is called the "single" vector processing method. If one uses this method for data compiled in the G-file, the G-file may include all possible unique combinations (independent and dependent) of the vectors. With this method there will be $n(n-1)/2$ possible vectors for each observing session, where n is the number of receivers simultaneously observing during the session. If only the (n-1) independent vectors are submitted, then every effort must be made to submit the shortest vectors since these are most likely to be the results of fixed integer bias solutions.

If processing all data collected during an independent observing session in a combined multiple vector solution the computation is called the "session" processing method. The session G-file entry would include results for the (n-1) independent vectors, where n is equal to the number of receivers collecting data simultaneously during the unique observing session.

If processing multiple sessions in a combined solution the result is called a "network" solution. The G-file would contain (s-1) independent vectors from each network solution, where s is the total number of unique stations incorporated in the solution.

The vectors generated in the "fixed orbit" solution mode using either the "broadcast" (predicted) or "precise" (post fit) ephemerides will be referenced to the satellite or fiducial station coordinate system. The current broadcast ephemeris coordinate system is known as the World Geodetic System 1984 (WGS 84) (DMA 1987). All analyses submitted to NGS, including minimally constrained or "free" adjustments, will be completed in the WGS 84 system or an internationally recognized coordinate system.

3.0 GPS PROJECT AND STATION OCCUPATION DATA FILE (B-file): Submit one B-file for each project. It may be created by using a program like CR8BB (NGS 1990). The software functions independently of the type of receivers used during the project.

The B-file contains information related to the project (such as name, location, etc.) and information for each station occupation [such as observer's initials, model and serial number of equipment, best estimates for the station coordinates, weather data, antenna height measurements (vertical), station name, operator comments, receiver time-offset measurements (if applicable), etc.].

B-file formats are described in Volume 1, Chapter 2.

4.0 STATION DESCRIPTION FILE (D-file): Create one D-file for each GPS project. This file contains descriptive or recovery information for each station visited during the GPS survey. It would include any points connected to the GPS survey using conventional horizontal surveying and/or differential leveling techniques, and miscellaneous reports for NGRS points visited but not occupied during the GPS survey. Submit the file in agreement with the format described in volume I, Chapter 3 and annexes C, D and I.

New descriptions should be created using program DESC which is part of a set of programs called DDPROC (NGS 1992). Descriptive data for existing NGRS points in a project area should be requested from NGS prior to starting reconnaissance. The data can be downloaded from the NGS data base and converted to a form usable by the DESC program for updating purposes.

5.0 HORIZONTAL CONNECTION SURVEY DATA FILE (T-file): A T-file must be created and submitted with the GPS project if the project includes any surveys observed with conventional (terrestrial) horizontal surveying techniques. For example, if an existing station was not a suitable GPS site and an offset point was used, the data compiled in the T-file would be for the horizontal tie between the two points. The T-file may be created with MTEN (NGS 1991b).

T-file formats are described in volume I, chapters 1 and 2.

6.0 VERTICAL CONNECTION SURVEY DATA FILE (L-file): If the GPS survey project includes observations using conventional differential leveling techniques, an L-file must be created and submitted with the GPS project data. For example, if a bench mark could not be occupied directly with a GPS receiver system and an offset point was set, part of the data entered connecting the two points together would be for the leveling observations between the two points.

If only one NGRS vertical point (bench mark) was leveled to at a GPS station site, the leveling data will be considered part of the GPS survey. If a good two-bench mark tie is made to the NGS Vertical control network, the leveling will be considered as a vertical control survey. Formats for these data are in Volume II.

Create the L-file with NGS software called PCvOBS (NGS 1989). Note that this program is to be used in place of program MTEN.

7.0 ANALYSIS AND ADJUSTMENT DATA:

7.1 Loop misclosures and differences in repeat vector measurements should be computed and evaluated to check for blunders or significant vector errors. They are also used to obtain initial estimates of the consistency of the GPS survey network. They should be done according to the "Office Procedures" in the publication, "Geometric Accuracy Standards and Specifications for GPS Relative Positioning Surveys" (FGCC 1989). Note that these checks are not an indication of accuracy but rather a measure of precision or repeatability.

Particular attention shall be given to detection of possible blunders caused by antenna offset measurements (vertical) and/or centering errors (horizontal). A tabulation of the results of repeat vector comparisons will be included in the project report.

7.2 A minimally constrained (free) least squares, three dimensional (3D) adjustment (one station arbitrarily selected and held equal to known, i.e published, NGRS coordinates) will be completed in accordance with the "Office Procedures" of the "Geometric Accuracy Standards and Specifications for GPS Relative Positioning Surveys" (FGCC 1989).

Submit a computer listing (burst and bound) that shall clearly include at least the following:

(a) Input vector component data. (Depending on adjustment software used, this may include variance-covariance data.)
(b) The "a priori" standard errors used if variance-covariance data were not used.
(c) Station list with name (abbreviated as appropriate), project unique four-character identification code, project unique numeric code used in adjustment, initial coordinates (latitude, longitude, and height above ellipsoid), and the fixed station specified.
(d) Adjusted vectors with residuals (v) and normalized residuals (v').
(e) "A posteriori" variance of unit weight of the adjustment.
(f) Adjusted coordinates for each station including the station held fixed in the "free" adjustment.
(g) Datum for the satellite coordinate system (e.g., WGS 84).
(h) The reference ellipsoid used in the adjustment. (e.g. WGS 84 or GRS 80)
(i) Other appropriate data or statistics.

The estimate of the variance factor ("a posteriori" variance of unit weight) should be less than 2 in the "free" (minimally constrained) adjustment. It may range between 1 and 16 or more depending upon how close the variance estimates for the vector components of the vector solutions are to the true values.

Estimates which are optimistic (i.e., too small) will result in higher variance factor values. Show clearly the name and version of the 3D adjustment software used.

7.3 A constrained 3D adjustment shall be submitted if project specifications require the computation of adjusted coordinates for the new points in relation to the local datum. A constrained adjustment for a project in North or Central America involves adjusting the GPS vector data while constraining stations to the existing network of NGS published horizontal coordinate data in the North American Datum of 1983 (NAD 1983) system and NGS published vertical data in the North American Vertical Datum of 1988 (NAVD 1988) system or their successors.

The unknown orthometric heights will be determined by the most appropriate method for achieving the specified accuracy standard for the project. This will usually involve one of two methods. The first method incorporates "a priori" geoidal undulation data in the 3D adjustment while holding fixed the orthometric heights for stations with known values (determined by differential leveling techniques). The source for the geoidal separation data (e.g., GEOID 93) must be given. This includes the name of software, version, and data used for computing the geoidal separation.

The second method for determining orthometric heights from GPS vector data involves performing 3D adjustments using no geoidal undulation data. In this method, the orthometric heights are held fixed while using zero values for the geoid height above the ellipsoid in the 3D adjustment. This forces the GPS network to fit to the geoidal surface. The success of achieving the specified accuracy standard for the orthometric heights at the points with unknown values will depend upon the flatness of the geoid in the project area and the distribution of the stations with known orthometric heights. This method is discussed in more detail in the article "On the use of GPS vectors in densification adjustments" (Vincenty 1987).

A tabulated listing of stations and fixed and adjusted coordinate values must be provided. The project report must give a description of the method used to estimate the orthometric heights.

8.0 PROJECT SKETCH: A sketch will be drawn in black ink on white paper showing all stations occupied during the GPS survey. **The sketch will have a border drawn around the edge and must include grid ticks for latitude and longitude**. Use the following standard symbols for the stations:

(a) Squares for existing vertical network control
(b) Open triangles for existing horizontal control stations
(c) Open triangles within squares for existing horizontal/vertical stations
(d) Closed triangles for GPS stations
(e) Circles for stations occupied during previous GPS projects

A "D" next to the station symbol will be used to indicate a Doppler station that has point-position coordinates determined using "precise" ephemerides. (Contact NGS for a list of Doppler stations with "precise" ephemerides point position coordinates located in North America.)

Besides the stations occupied, the sketch should show other stations of the existing network located within or near the project area. Specify in the project report whether any attempt was made to recover these stations. The report must state why the recovered stations were not occupied. To show a station that was not recovered use "NR" next to that station's symbol. The sketch shall include a boxed-in legend that gives:

(a) project name
(b) general locality
(c) name of group making observations
(d) project leader
(e) month/year (from-to)
(f) scale of sketch

On a copy of the sketch, form closed loops of all (if practical) "independent" (non-trivial) GPS vectors measured. Show vectors common to an observing session with different line types (dashed, dotted, etc., or other clear graphic depiction). Show, next to one or more of the independent lines for each session, the observing day number/session designation (e.g., 242B, 321C, 3331, 3332, etc.).

Survey points will be shown in an inset sketch when they are too close together to be depicted clearly on the network sketch. The project sketch(es) will be included with the project report.

9.0 PROJECT REPORT: The project report will be submitted in a binder with the project name on the front of the binder and will be structured in the following manner:

I. Introduction

A. Purpose - Describe the purpose for which the survey was conducted. Show the name of the organization for which the survey was performed.

B. Time Period - State the arrival and departure dates for the field crew
and dates of first and last observing sessions.

C. Point of Contact - Supply the name, phone number, and mailing address of the point of contact within the submitting organization. Supply the same information for all organizations which participated in the survey.

D. Accuracy standards - Provide the accuracy standards (vertical and horizontal) specified for the project.

II. Location - Describe the geographic location and scope of the project in general terms.

III. Conditions Affecting Progress - Specify equipment failures, climate, scope of project, site accessibility, reconnaissance, malfunctioning satellites, etc.

IV. Field Work

A. Chronology - Give a brief description of the progression of the project.

B. Instrumentation - Describe the make, model, and serial number of each receiver used on the project.

C. Deviation from Instructions - Describe any deviation from the procedures and specifications stated in the project instructions. Specify all stations which were eccentrically occupied and state why the station(s) could not be directly occupied.

V. Data Processing Performed - Describe the data processing that was done. Include tasks such as transferring of data to different storage media, data quality checking, station descriptions, vector determinations, and closure computations. Specify the ephemeris type [broadcast (predicted) or precise (post fit)] and the source.

Complete the following sections as appropriate:

A. Software Used - Specify all software by program name and version number which was used to acquire, manage, reduce, adjust, and submit field data. If the project data were reduced or acquired with different versions of a program, specify which version was used with which block of data.

B. Rejected Data - Specify observing sessions which were rejected and reobserved. Include the reason(s) why the data from a particular session were rejected.

C. Equipment - Describe by manufacturer, model number, and serial number all receivers used to collect the data. Indicate any equipment failures which may have degraded the quality of data and/or vector determinations which were retained. Specify the data or vectors by station and session, and the failed equipment by component and serial number. Indicate data rejected because of equipment failure in section B above.

D. Weather - Tabulate required meteorological observations for the survey and include a copy with this report. List all observing sessions which occurred during periods of changing or severe weather conditions such as passing fronts, storms, etc. A simple table listing the sessions influenced and the weather condition will suffice.

E. Adjustment - Discuss in detail the type(s) of adjustment(s) performed. Show weighting technique used, station(s) constrained, method used to estimate orthometric heights and existence of independent sub-networks. Discuss possible weaknesses or distortions found or suspected in the NGRS.

F. Closures - Tabulate the results of all loop misclosure computations. Include the vectors used, vector length, maximum closure error in each component, and average closure error in each component. Tabulate closure component error in terms of Cartesian coordinates (XYZ) and in terms of the local terrestrial system [N,E,U (north, east, up)]. Also, tabulate comparisons of repeat vectors observed indicating vector length, and maximum and average closure for each vector component. Closures will be stated in both meters and parts per million.

VI. Statistics

A. Stations Occupied - List station names and give total stations occupied based on each of the following categories:

1. Existent NGRS horizontal stations
2. Existent NGRS vertical stations
3. Existent NGRS horizontal/vertical stations
4. Stations established
5. Stations previously occupied with GPS

B. Base lines Observed - Compute the total number of independent (non-trivial) vectors observed during the project. Each observing session cannot have more than (N - 1) independent vectors, where N = number of receivers. For example, if a project included 10 observing sessions and 4 receivers were used during each session, a total of 10(4-1) = 30 independent vectors would have been observed.

C. Provide the total number of observing days and total number of sessions. For example, if the total number of observing days was 5 and there were 2 sessions conducted each observing day, then the total number of observing sessions was 5 x 2 = 10.

VII. Comments and Recommendations

Include noteworthy comments and recommendations regarding the execution of the GPS survey for this project (or future projects) not found elsewhere in the project report.

VIII. Attachments and Enclosures

A. Station List - Include a table which lists the station name, four-character station identifier, coordinates, elevation, session(s) occupied, and station type for all stations occupied. The list will be alphabetical by four-character identifier. See "Planning GPS Surveys" for instructions on preparation of station lists (NGS 1986).

B. Field Project Sketch - Attach a copy of the project sketch. If there are multiple copies of the sketch showing different data, attach a copy of each. See "Planning GPS Surveys" for instructions on preparation of survey sketches (NGS 1986).

C. Project Instructions - Attach a copy of the instructions and/or contract under which this project was performed. Also include any revisions or changes to the instructions or specifications.

D. Field Logs - Provide original or clear copies of field survey notes, record books, and observation logs. When appropriate, this will include Log of Time Offset Measurements and Log of Surface Meteorological Measurements.

E. Equipment Failure Logs - Include with the report a failure log for any equipment used to gather data which failed anytime during the project. The log will state the name of the component, serial number, date of failure and nature of failure.

F. Project Observing Schedule - Prepare a list which summarizes the following: observing day numbers/session letters, four-character station identifiers, start and stop dates and times (UTC), satellites observed (PRN numbers), receiver serial numbers, antenna offset measurements, remarks, etc.

All data and material submitted must be neat and legible (typed or clearly written in black ink). DO NOT SEND THE ONLY COPY OF ANY PAPER RECORDS OR DIGITAL DATA FILES.

10.0 PROJECT SUBMISSION CHECKLIST: Exhibit A is a form that may be used to check for completeness when submitting GPS project data to the National Geodetic Survey.

11.0 DATA TRANSMISSION MEDIA: **All** computer-generated digital data files must be submitted to the NGS in digital form on media approved by NGS at time of submission.

If you have questions concerning the above requirements, please contact:

Ms. Madeline White
National Geodetic Survey
NOAA, N/NGS42
1315 East-West Highway, Station 8432
Silver Spring, Maryland 20910-3282

Telephone: 301-713-3211, Ext. 188

EXHIBIT A

PROJECT SUBMISSION CHECKLIST
GPS PROJECTS

Project Title: _____

Accession Number: _____

Submitting Agency: _____

Observing Agency: _____

Receiver Type: _____

PACKAGE CONTENTS

Project Report and Attachments	**Required For**
( ) Project Report	All Projects
( ) **Approved Reconnaissance** and Project Sketch	All Projects
( ) Project Instructions or Contract Specifications	All Projects
( ) Final Station List	All Projects
( ) Station Visibility Diagrams	All Projects
( ) Final Observing Schedule	All Projects
( ) Observation Logs	All Projects
( ) Equipment Failure Logs	NGS Projects
( ) Loop Misclosures	**Optional**
( ) Free Adjustment **with Analysis**	All Projects
( ) Free Adjustment with Accuracies	**All Projects**
( ) Constrained Horizontal Adjustment	All Projects
( ) Constrained Vertical Adjustment (NAVD 88 Heights)	**All Projects**
( ) Meteorological Instrument Comparison Logs	If Specified
( ) Photographs of Views from Stations	If Specified
( ) Photographs or Rubbings of Station Marks	All Projects
( ) COMPGB Output (Validation program-B/G file)	All Projects
( ) OBSDES Output (Validation program-D-file)	All Projects
( ) OBSCHK Output (Validation program-D-file)	**All Projects**
( ) CHKDESC Output (Validation program-D-file)	**All Projects**
( ) ELLACC Output	**All Projects**
( ) BBACCUR Output	**All Projects**

Digitized Data Files **( ) Diskettes ( ) Other:**_____

( ) Raw Phase Data (R-files)	All Projects
( ) Base Line Vectors (G-file)	All Projects
( ) Project and Station Occupation Data(Final B-file)	All Projects
( ) Descriptions or Recovery Notes (D-file)	All Projects
( ) Terrestrial Horizontal Observations (T-file)	If Applicable
( ) Differential Leveling Observations (L-file)	If Applicable

Comments - Enter on the reverse side of this form.

Org Code **Name** **Date**

Received by: _____

Reviewed by: _____

Reviewed by: _____

REFERENCES:

Defense Mapping Agency, 1987: Department of Defense World Geodetic System 1984 - its definition and relationships with local geodetic systems. DMA Technical Report, DMA TR 8350.2, 30 September 1987, Washington, DC, 121 pp.

Federal Geodetic Control Committee, 1989: Geometric Accuracy Standards and Specifications for GPS Relative Positioning Surveys, version 5.0: May 11, 1988, reprinted with corrections August 1, 1989, 48 pp.

National Geodetic Survey, 1992: "Program DDPROC and Documentation," version 2.0: December 10, 1992.

National Geodetic Survey, 1991a: "Program LOOP and Documentation," version 4.03: January 18, 1991.

National Geodetic Survey, 1991b: "MTEN4, A System for Use with the National Geodetic Survey Data Base Input Formats and Specifications", version 20: December, 1991.

National Geodetic Survey, 1990: "Guidelines for Digitizing GPS Project and Station Occupation Information using program CR8BB," version 3.21: July 26, 1990.

National Geodetic Survey, 1989: "PCvOBS Software and Documentation," version 2.00: October 10, 1989.

National Geodetic Survey, 1988: "Program CR8G and Documentation," version 1.1: December 27, 1988.

National Geodetic Survey, 1986: "Planning GPS Surveys," version 2, September 26, 1986 (NGS preliminary document).

Vincenty, T., 1987: "On the use of GPS vectors in densification adjustments," Surveying and Mapping (Journal of the American Congress on Surveying and Mapping), Vol. 47, No. 2, pp. 103-108.

NOTE: All National Geodetic Survey and Federal Geodetic Control Subcommittee publications are available from:

NOAA, National Geodetic Information Branch, N/NGS12
1315 East-West Highway, Room 9202
Silver Spring, MD 20910-3282.

phone: 301-713-3242
fax: 301-713-4172